WHAT IS CLAIMED IS:

1. An optical mode transformer comprising:

a substrate;

a lower waveguide cladding layer disposed on the substrate, the lower waveguide cladding layer having a first refractive index and an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding layer, the waveguide core having a long axis, the waveguide core having a second refractive index, the ratio of the second refractive index to the first refractive index being at least about 1.3, the waveguide core further having a first end optically coupled to a small beam port, a second end defining an intermediate beam port, and an upper surface;

side waveguide cladding disposed on the upper surface of the lower waveguide cladding layer adjacent to both sides of the waveguide core, the side waveguide cladding having a third refractive index, the ratio of the second refractive index to the third refractive index being at least about 1.3, the side waveguide cladding further having an upper surface; and

an upper waveguide cladding layer disposed on the upper surface of the waveguide core and the upper surface of the side waveguide cladding, the upper waveguide cladding having a fourth refractive index, the ratio of the second refractive index to the fourth refractive index being at least about 1.3;

the optical mode transformer being configured such that the waveguide core has a vertical taper wherein a thickness of the waveguide core in a dimension normal to the substrate surface decreases along the long axis from a first thickness value at a first point near the small beam port to a second thickness value at a second point near the intermediate beam port, the second thickness value being smaller than a critical thickness value, the critical thickness value being defined as a thickness value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size.

2. An optical mode transformer for guiding a light beam and transforming a mode size of the light beam, the optical mode transformer having a small beam port at a small-beam end and a large beam port at a large-beam end, the optical mode transformer comprising:

a substrate;

a lower waveguide cladding layer disposed on the substrate, the lower waveguide cladding layer having a first refractive index and an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding layer, the waveguide core having a long axis and having a cross section in a plane normal to the long axis, the waveguide core having a second refractive index, the ratio of the second refractive index to the first refractive index being at least about 1.3, the waveguide core further having a first end optically coupled to the small beam port, a second end defining an intermediate beam port, and an upper surface;

side waveguide cladding disposed on the upper surface of the lower waveguide cladding and adjacent to the waveguide core, the side waveguide cladding having a third refractive index, the ratio of the second refractive index to the third refractive index being at least about 1.3, the side waveguide cladding further having an upper surface; and

an upper waveguide cladding disposed on the upper surface of the waveguide core and the upper surface of the side waveguide cladding, said upper waveguide cladding having a fourth refractive index, the ratio of the second refractive index to the fourth refractive index being at least about 1.3;

the optical mode transformer being configured such that:

in a first region along the long axis between the small beam port and a transition point, the waveguide core cross section has a thickness in a dimension normal to the substrate surface that is substantially constant and equal to a first thickness value;

in a second region along the long axis between the transition point and the intermediate beam port, the waveguide core cross section has a thickness that changes along the long axis from the first thickness value to a second thickness value smaller than the first thickness value, the second thickness value being smaller than a critical thickness value, the critical thickness value being defined as a thickness value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size; and

in a third region along the long axis between the intermediate beam port and the large beam port, the waveguide core cross section has a thickness that is substantially constant and approximately equal to the second thickness value.

3. The optical mode transformer of claims 1 or 2, wherein the second thickness value is substantially equal to zero.

4. The optical mode transformer of claims 1 or 2, wherein the thickness of the waveguide core changes substantially uniformly from the first thickness value to the second thickness value.

5. The optical mode transformer of claims 1 or 2, wherein the substrate comprises silicon.

6. The optical mode transformer of claims 1 or 2, wherein the waveguide core comprises silicon.

7. The optical mode transformer of claims 1 or 2, wherein the lower waveguide cladding comprises silicon dioxide.

8. The optical mode transformer of claims 1 or 2, wherein each of the side waveguide cladding and the upper waveguide cladding comprises a mixture of silicon dioxide and titanium dioxide.

9. The optical mode transformer of claim 2, wherein a light beam having an initial mode size enters the waveguide core from the small beam port and exits at the large beam port having a final mode size larger in a dimension normal to the substrate surface than the initial mode size.

10. The optical mode transformer of claim 2, wherein a light beam having an initial mode size enters at the large beam port and exits the waveguide core at the small beam port having a final mode size smaller in a dimension normal to the substrate surface than the initial mode size.

11. The optical mode transformer of claims 1 or 2, wherein the waveguide core further has a lateral taper along the direction of light propagation, wherein a width of the waveguide core in a dimension parallel to the substrate surface and transverse to the direction of light propagation increases from a first width to a second width, the second width being substantially equal to a desired large mode size of a light beam.

12. The optical mode transformer of claims 1 or 2, wherein the waveguide core further has a lateral taper along the direction of light propagation, whereina width of the waveguide core decreases from a first width value to a second width value, the second width value being smaller than a critical width value, the critical width value being defined as a width value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into the side waveguide cladding, thereby enlarging the small mode size.

13. An optical mode transformer comprising:

a substrate;

a lower waveguide cladding layer disposed on the substrate and having a first refractive index and an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding layer, the waveguide core having a long axis, the waveguide core having a second refractive index, the ratio of the second refractive index to the first refractive index being at least about 1.3, the waveguide core further having a first end optically coupled to a small beam port, a second end defining an intermediate beam port, and an upper surface;

side waveguide cladding disposed on the upper surface of the lower waveguide cladding layer adjacent to both sides of the waveguide core, the side waveguide cladding having a third refractive index, the ratio of the second refractive index to third refractive index being at least about 1.3, the side waveguide cladding further having an upper surface; and

an upper waveguide cladding layer disposed on the upper surface of the waveguide core and the upper surface of the side waveguide cladding, the upper waveguide cladding having a fourth refractive index, the ratio of the second refractive index to the fourth refractive index being at least about 1.3;

the optical mode transformer being configured such that the waveguide core has a lateral taper wherein a width of the waveguide core in a dimension parallel to the substrate surface and transverse to the long axis decreases along the direction of light propagation from a first width value at a first point near the small beam port to a second width value at a second point near the intermediate beam port, the second width value being smaller than a critical width value, the critical width value being defined as a width value below which a significant portion of the energy of a light beam having a small mode size

received at the small beam port and propagating in the waveguide core penetrates into the side waveguide cladding, thereby enlarging the small mode size.

14. An optical mode transformer comprising:

a substrate;

a lower waveguide cladding layer disposed on the substrate and having a first refractive index and an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding layer, the waveguide core having a long axis and having a cross section in a plane normal to the long axis, the waveguide core having a second refractive index, the ratio of the second refractive index to the first refractive index being at least about 1.3, the waveguide core further having a first end optically coupled to a small beam port, a second end defining an intermediate beam port, and an upper surface;

side waveguide cladding disposed on the upper surface of the lower waveguide cladding and adjacent to the waveguide core, the side waveguide cladding having a third refractive index, the ratio of the second refractive index to the third refractive index being at least about 1.3, the side waveguide cladding further having an upper surface; and

an upper waveguide cladding disposed on the upper surface of the waveguide core and the upper surface of the side waveguide cladding, said upper waveguide cladding having a fourth refractive index, the ratio of the second refractive index to the fourth refractive index being at least about 1.3;

the optical mode transformerbeing configured such that:

in a first region along the long axis between the small beam port and a transition point, the waveguide core cross section has a width that is substantially constant and equal to a first width value;

in a second region along the long axis between the transition point and the intermediate beam port, the waveguide core cross section has a width in a dimension parallel to the substrate surface and transverse to the long axis that changes along the long axis from the first width value to a second width value smaller than the first width value, the second width value being smaller than a critical width value, the critical width value being defined as a width value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into the side waveguide cladding, thereby enlarging the small mode size; and

in a third region along the long axis between the intermediate beam port and a large beam port, the waveguide core cross section has a width that is substantially constant and approximately equal to the second width value.

15. The optical mode transformer of claims 13 or 14, wherein the second width value is substantially equal to zero.

16. The optical mode transformer of claims 13 or 14, wherein the width of the waveguide core changes substantially uniformly from the first width value to the second width value.

17. The optical mode transformer of claims 13 or 14, wherein the substrate comprises silicon.

18. The optical mode transformer of claims 13 or 14, wherein the waveguide core comprises silicon.

19. The optical mode transformer of claims 13 or 14, wherein the lower waveguide cladding comprises silicon dioxide.

20. The optical mode transformer of claims 13 or 14, wherein each of the side waveguide cladding and the upper waveguide cladding comprises a mixture of silicon dioxide and titanium dioxide.

21. The optical mode transformer of claim 14, wherein a light beam having an initial mode size enters the waveguide core form the small beam port and exits at the large beam port, having a final mode size larger in a dimension parallel to the substrate surface and transverse to the direction of light propagation than the initial mode size.

22. The optical mode transformer of claim 14, wherein a light beam having an initial mode size enters the waveguide core from the large beam port and exits at the small beam port having a final mode size larger in a dimension parallel to the substrate surface and transverse to the direction of light propagation than the initial mode input beam.

23. The optical mode transformer of claims 13 or 14, wherein the waveguide core further has a vertical taper along the direction of light propagation, wherein a thickness of the waveguide core in a dimension normal to the substrate surface increases

from a first thickness to a second thickness, wherein the second thickness is approximately equal to a desired large mode size of a light beam.

24. The optical mode transformer of claims 13 or 14, wherein the waveguide core has a vertical taper along the direction of light propagation, wherein a thickness of the waveguide core in a dimension normal to the substrate surface decreases from a first thickness value to a second thickness value, the second thickness value being smaller than a critical thickness value, the critical thickness value being defined as a thickness value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size.

25. An optical mode transformer comprising:

a substrate;

a lower waveguide cladding layer disposed on the substrate and having a first refractive index, an upper surface and side surfaces;

a waveguide core disposed on the upper surface of the lower waveguide cladding layer, the waveguide core having a long axis, the waveguide core having a second refractive index, the ratio of the second refractive index to the first refractive index being at least about 1.3, the waveguide core further having a first end optically coupled to a small beam port, a second end defining an intermediate beam port, and an upper surface;

side waveguide cladding disposed on the side surfaces of the lower waveguide cladding layer adjacent to both sides of the waveguide core, the side waveguide cladding having a third refractive index, the ratio of the second refractive index to the third refractive index being at least about 1.3, the side waveguide cladding further having an upper surface; and

an upper waveguide cladding layer disposed on the upper surface of the waveguide core and the upper surface of the side waveguide cladding, the upper waveguide cladding having a fourth refractive index, the ratio of the second refractive index to the fourth refractive index being at least about 1.3;

the optical mode transformer being configured such that the waveguide core has a lateral taper wherein a width of the waveguide core in a dimension parallel to the substrate surface and transverse to the long axis increases along the direction of light

propagation from a first width value at a first point near the small beam port to a second width value at a second point near the intermediate beam port, the second width value being substantially equal to a desired value that defines a large mode size of a light beam.

26. An optical mode transformer comprising:

a substrate;

a lower waveguide cladding layer disposed on the substrate and having a first refractive index, an upper surface and side surfaces;

a waveguide core disposed on the upper surface of the lower waveguide cladding layer, the waveguide core having a long axis and having a cross section in a plane normal to the long axis, the waveguide core having a second refractive index, the ratio of the second refractive index to the first refractive index being at least about 1.3, the waveguide core further having a first end optically coupled to a small beam port, a second end defining an intermediate beam port, and an upper surface;

side waveguide cladding disposed on the side surfaces of the lower waveguide cladding and adjacent to the waveguide core, the side waveguide cladding having a third refractive index, the ratio of the second refractive index to the third refractive index being at least about 1.3, the side waveguide cladding further having an upper surface; and

an upper waveguide cladding disposed on the upper surface of the waveguide core and the upper surface of the side waveguide cladding, said upper waveguide cladding having a fourth refractive index, the ratio of the second refractive index to the fourth refractive index being at least about 1.3;

the optical mode transformer being configured such that:

in a first region along the direction of light propagation between the small beam port and a transition point, the waveguide core cross section has a width in a dimension parallel to the substrate surface and transverse to the long axis that is substantially constant and equal to a first width value;

in a second region along the direction of light propagation between the transition point and the intermediate beam port, the waveguide core cross section has a width that changes along the long axis from the first width value to a second width value larger than the first width value, the second width value being substantially equal to a desired value that defines a large mode size of a light beam; and

in a third region along the direction of light propagation between the intermediate beam port and a large beam port, the waveguide core cross section has a width that is approximately constant and equal to the second width value.

27. The optical mode transformer of claims or , wherein the second width value is substantially equal to a mode size of an optical fiber.

28. The optical mode transformer of claims or , wherein the width of the waveguide core changes substantially uniformly from the first width value to the second width value.

29. The optical mode transformer of claims 25 or 26, wherein the substrate comprises silicon.

30. The optical mode transformer of claims 25 or 26, wherein the waveguide core comprises silicon.

31. The optical mode transformer of claims 25 or 26, wherein the lower waveguide cladding comprises silicon dioxide.

32. The optical mode transformer of claims 25 or 26, wherein each of the side waveguide cladding and the upper waveguide cladding comprises a mixture of silicon dioxide and titanium dioxide.

33. The optical mode transformer of claim 26, wherein a light beam having an initial mode size enters the waveguide core from the small beam port and exits at the large beam port having a final mode size larger in a dimension parallel to the substrate surface and transverse to the direction of light propagation than the initial mode size.

34. The optical mode transformer of claim 26, wherein a light beam having an initial mode size enters the waveguide core at the large beam port and exits at the small beam port having a final mode size smaller in a dimension parallel to the substrate surface and transverse to the direction of light propagation than initial mode size.

35. The optical mode transformer of claims 25 or 26, wherein the waveguide core further has a vertical taper along the direction of light propagation, wherein a thickness of the waveguide core in a dimension normal to the substrate surface to increase

from a first thickness value to a second thickness value, wherein the second thickness value is approximately equal to a desired large mode size of a light beam.

36. The optical mode transformer of claims 25 or 26, wherein the waveguide core has a vertical taper along the direction of light propagation, wherein a thickness of the waveguide core in a dimension normal to the substrate surface to decrease from a first thickness value to a second thickness value, the second thickness being smaller than a critical thickness value, the critical thickness value being defined as a thickness value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size.

37. An optical waveguide comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface;

a non-cylindrical waveguide core aligned in axial direction disposed on the lower waveguide cladding; said waveguide core having a center and an outer border; and

an upper waveguide cladding disposed on the waveguide core,

the waveguide core having a refractive index having a value that is graded in the y-coordinate and gradually decreases from a maximum effective refractive index at the center of the core to a minimum effective refractive index at the outer border of said waveguide core, the y-coordinate representing a distance from the substrate surface.

38. The optical waveguide of claim 37, wherein said waveguide core has a refractive index that is graded in the x-coordinate and gradually decreases from a maximum effective refractive index at the center of the core to a minimum effective refractive index at the outer border of said waveguide core, the x-coordinate representing a direction transverse to said y-coordinate and perpendicular to said axial direction.

39. The optical waveguide of claim 37, wherein said waveguide core has a refractive index that is constant in the x-coordinate, the x-coordinate representing a direction transverse to said y-coordinate and perpendicular to said axial direction.

40. An optical waveguide comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface;

a non-cylindrical waveguide core aligned in an axial direction disposed on the lower waveguide cladding; said waveguide core having a center and an outer border;

an upper waveguide cladding disposed on the waveguide core,

the waveguide core having a first refractive index distribution that is graded in a first direction normal to the substrate surface and that gradually decreases from a maximum effective refractive index at the center of the core to a first minimum effective refractive index at the outer border of said waveguide core,

and wherein said waveguide core has a second refractive index distribution that is graded in a second direction transverse to said first direction perpendicular to said axial direction and that gradually decreases from said maximum effective refractive index at the center of the core to a second minimum effective refractive index at the outer border of said waveguide core.

41. An optical waveguide comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface;

a non-cylindrical waveguide core aligned in an axial direction disposed on the lower waveguide cladding; said waveguide core having a center and an outer border;

an upper waveguide cladding disposed on the waveguide core,

the waveguide core having a refractive index having a value that is graded in the y-coordinate and gradually decreases from a maximum effective refractive index at the center of the core to a minimum effective refractive index at the outer border of said waveguide core, the y-coordinate representing a distance from the substrate surface,

and wherein said waveguide core has a refractive index that is constant in the x-coordinate, the x-coordinate representing a direction transverse to said y-coordinate and perpendicular to said axial direction.

42. An optical waveguide comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface;

a non-cylindrical waveguide core aligned in axial direction disposed on the lower waveguide cladding; said waveguide core having a center and an outer border; and

an upper waveguide cladding disposed on the waveguide core,

the waveguide core having a refractive index having a value that is constant in the y-coordinate, the y-coordinate representing a distance from the substrate surface.

43. The optical waveguide of claim 42, wherein said waveguide core has a refractive index that is graded in the x-coordinate and gradually decreases from a maximum effective refractive index at the center of the core to a minimum effective refractive index at the outer border of said waveguide core, the x-coordinate representing a direction transverse to said y-coordinate and perpendicular to said axial direction.

44. The optical waveguide of claim 42, wherein said waveguide core has a refractive index that is constant in the x-coordinate, the x-coordinate representing a direction transverse to said y-coordinate and perpendicular to said axial direction.

45. An optical waveguide comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface;

a non-cylindrical waveguide core aligned in axial direction disposed on the lower waveguide cladding; said waveguide core having a center and an outer border; and

an upper waveguide cladding disposed on the waveguide core,

the waveguide core having a refractive index having a value that is constant in the y-coordinate, the y-coordinate representing a distance from the substrate surface,

and wherein said waveguide core has a refractive index that is graded in the x-coordinate and gradually decreases from a maximum effective refractive index at the center of the core to a minimum effective refractive index at the outer border of said waveguide core, the x-coordinate representing a direction transverse to said y-coordinate and perpendicular to said axial direction.

46. An optical waveguide comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface;

a non-cylindrical waveguide core aligned in axial direction disposed on the lower waveguide cladding; said waveguide core having a center and an outer border; and

an upper waveguide cladding disposed on the waveguide core,

the waveguide core having a refractive index having a value that is constant in the y-coordinate, the y-coordinate representing a distance from the substrate surface,

and wherein said waveguide core has a refractive index that is constant in the x-coordinate, the x-coordinate representing a direction transverse to said y-coordinate and perpendicular to said axial direction.

47. An optical mode transformer comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface, the lower waveguide cladding having a refractive index distribution that varies according to a first function of a y-coordinate, the y-coordinate representing a distance from the substrate surface, the first function having a maximum value and a minimum value, the lower waveguide cladding further having an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding, the waveguide core having a core refractive index, the ratio of the core refractive index to the maximum value of the first function being at least about 1.3, the waveguide core further having a first end located substantially at a small beam port, a second end defining an intermediate beam port, and an upper surface; and

an upper waveguide cladding disposed on the upper surface of the waveguide core and on the upper surface of the lower waveguide cladding, the upper waveguide cladding having a refractive index distribution that varies as a second function of a y-coordinate, the second function having a maximum value and a minimum value, the ratio of the core refractive index to the maximum value of the second function being at least about 1.3;

the optical mode transformer being configured such that the waveguide core has a vertical taper along the long axis, the vertical taper being a changing thickness of the waveguide core in a dimension normal to the substrate surface, wherein the thickness decreases along the long axis from a first thickness value at a first point near the small beam port to a second thickness value at a second point near the intermediate beam port, the second thickness value being less than a critical thickness value, the critical thickness value being defined as a thickness value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size.

48. The optical mode transformer of claim 47, further comprising a low refractive index buffer layer between said waveguide core and said lower waveguide cladding.

49. The optical mode transformer of claim 47, further comprising a low refractive index buffer layer between said waveguide core and said upper waveguide cladding.

50. An optical mode transformer comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface, the lower waveguide cladding having a refractive index distribution that varies according to a first function of a y-coordinate, the y-coordinate representing a distance from the substrate surface, the first function having a maximum value and a minimum value, the lower waveguide cladding further having an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding, the waveguide core having a core refractive index, the ratio of the core refractive index to the maximum value of the first function being at least about 1.3, the waveguide core further having a first end located substantially at a small beam port, a second end defining an intermediate beam port, and an upper surface; and

an upper waveguide cladding disposed on the upper surface of the waveguide core and on the upper surface of the lower waveguide cladding, the upper waveguide cladding having a refractive index distribution that varies as a second function of a y-coordinate, the second function having a maximum value and a minimum value, the ratio of the core refractive index to the maximum value of the second function being at least about 1.3;

the optical waveguide being configured such that:

in a first region along the long axis between the small beam port and a transition point, the waveguide core cross section has a thickness in a dimension normal to the substrate surface that is substantially constant and equal to a first thickness value;

in a second region along the long axis between the transition point and the intermediate beam port, the waveguide core cross section has a thickness that changes along the long axis from the first thickness value to a second thickness value smaller

than the first thickness value, the second thickness being small enough to cause a small mode size of a small light beam received at the small beam port to propagate into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size; and

in a third region along the long axis between the intermediate beam port and the large beam port, the waveguide core cross section has a thickness that is substantially constant and approximately equal to the second thickness value.

51. The optical mode transformer of claim 50, further comprising a low refractive index buffer layer between said waveguide core and said lower waveguide cladding.

52. The optical mode transformer of claim 50, further comprising a low refractive index buffer layer between said waveguide core and said lower waveguide cladding.

53. The optical mode transformer of claims 47 or 50, wherein:

the lower waveguide cladding comprises a first plurality of lower cladding layers substantially parallel to the substrate, wherein each lower cladding layer has a layer-specific refractive index that is a function of the y-coordinate; and

the upper waveguide cladding comprises a second plurality of upper cladding layers, wherein each upper cladding layer has a layer-specific refractive index that is a function of the y coordinate.

54. The optical mode transformer of claims 47 or 50, wherein, for any value of the y-coordinate:

the effective layer-specific refractive index of each of the first plurality of lower cladding layers is higher than the layer-specific refractive index of the lower cladding layer below; and

the effective layer-specific refractive index of each of the second plurality of upper cladding layers is lower than the layer-specific refractive index of the upper cladding layer below.

55. The optical mode transformer of claims 47 or 50, wherein the layer-specific refractive index of each of the first plurality of lower cladding layers forms a first refractive-index distribution that is symmetric with a second refractive-index distribution

formed by the layer-specific refractive index of each of the second plurality of upper cladding layers.

56. The optical mode transformer of claims 47 or 50, wherein the first and second distributions together comprise a substantially parabolic distribution.

57. The optical mode transformer of claims 47 or 50, wherein the first function has a substantially parabolic dependence on the y-coordinate and the second function has a substantially parabolic dependence on the y-coordinate.

58. The optical mode transformer of claims 47 or 50, wherein:

the difference between the maximum value of the first function and the minimum value of the first function is not less than about 0.02; and

the difference between the maximum value of the second function and the minimum value of the second function is not less than about 0.02.

59. The optical mode transformer of claims 47 or 50, wherein:

the first function is a constant function of the y-coordinate; and

the upper waveguide cladding comprises a plurality of upper cladding layers substantially parallel to the substrate, wherein each upper cladding layer has a layer-specific refractive index that is a function of the x coordinate.

60. The optical mode transformer of claims 47 or 50, wherein for any value of the y-coordinate:

the first function is a stepwise function of the x-coordinate having substantially a first value in a first range of x-coordinate values, substantially a second value in a second range of x-coordinate values, and substantially the first value in a third range of x-coordinate values, wherein the second value is higher than the first value and wherein the waveguide core is located at a position having x-coordinate values within the second range, wherein the x-coordinate is in the axial direction parallel to the surface of said optical mode transformer and perpendicular to the propagation direction of the light through said optical mode transformer.

61. The optical mode transformer of claims 47 or 50, wherein the waveguide core further has a lateral taper along the direction of light propagation, the lateral taper causing a width of the waveguide core in a dimension parallel to the substrate surface

and transverse to the direction of light propagation to increase from a first width value to a second width value, the second width value being substantially equal to a desired large mode size of a light beam.

62. The optical mode transformer of claims 47 or 50, wherein the waveguide core has a lateral taper along the direction of light propagation, the lateral taper causing a width of the waveguide core to decrease from a first width value to a second width value, the second width value being smaller than a critical width value, the critical width value being defined as a width value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into the waveguide cladding, thereby enlarging the small mode size.

63. The optical mode transformer of claims 47 or 50, wherein:

a light beam having a small mode size enters the optical waveguide at the small beam port, the small mode size being substantially equal to a mode size of a semiconductor optical device;

the light beam is modified to have an intermediate mode size as it passes through the second region; and

the light beam is further modified to have a large mode size as it passes through the third region, the large mode size being substantially equal to a mode size of an optical fiber.

64. The optical mode transformer of claims 47 or 50, wherein:

a light beam having a large mode size enters the optical waveguide at the large beam port, the large mode size being substantially equal to a mode size of an optical fiber;

the light beam is modified to have an intermediate mode size as it passes through the third region; and

the light beam is further modified to have a small mode size as it passes through the second and first regions to the small beam port, the small mode size being substantially equal to a mode size of a semiconductor optical device.

65. The optical mode transformer of claims 47 or 50, wherein:

a recess is formed in the substrate near the small beam port, the recess being configured for mounting of a semiconductor optical device in alignment with the small beam port; and

a groove is formed in the substrate near the large beam port, the groove being configured to hold an optical fiber in alignment with the large beam port.

66. The optical mode transformer of claim 65, wherein a semiconductor optical device is mounted in the recess.

67. The optical mode transformer of claim 65, wherein an optical fiber is mounted in the groove.

68. The optical mode transformer of claims 47 or 50, wherein:

the first function and the second function are chosen such that the upper and lower cladding provide a lens function in the third region, whereby a light beam propagating from the small beam port to the large beam port is caused to be enlarged and collimated.

69. The optical mode transformer of claim 50, wherein:

the first function and the second function are chosen such that the upper and lower cladding provide a lens function in the third region, whereby a light beam propagating from the large beam port to the small beam port is caused to be reduced and focused onto the intermediate beam port.

70. An optical mode transformer comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface, the lower waveguide cladding having a vertical refractive index having a vertical value that varies according to first substantially stepwise function of a y-coordinate, the y-coordinate representing a distance from the substrate surface, the first function having a maximum value and a minimum value, and the lower waveguide cladding having a horizontal refractive index having a horizontal value that varies according to first substantially stepwise function of an x-coordinate, the x-coordinate representing a position in a dimension parallel to the substrate surface and transverse to the long axis, the first function having a maximum value and a minimum value, the lower waveguide cladding further having an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding, the waveguide core having a core refractive index, the ratio of the core refractive index to the maximum value of the first function being at least about 1.3, the waveguide core further having a first end located substantially at the small beam port, a second end defining an intermediate beam port, and an upper surface; and

an upper waveguide cladding disposed on the upper surface of the waveguide core and on the upper surface of the lower waveguide cladding, the upper waveguide cladding having a refractive index having a value that varies as a second function of the y-coordinate and of the x-coordinate, the second function having a maximum value and a minimum value, the ratio of the core refractive index to the maximum value of the second function being at least about 1.3;

the optical mode transformer being configured such that the waveguide core has a vertical taper along the long axis, the vertical taper being a changing thickness of the waveguide core in a dimension normal to the substrate surface, wherein the thickness decreases along the long axis from a first thickness value at a first point near the small beam port to a second thickness value at a second point near the intermediate beam port, the second thickness value being less than a critical thickness value, the critical thickness value being defined as a thickness value below which a significant portion of the energy of a light beam having a small mode size received at the small beam port and propagating in the waveguide core penetrates into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size.

71. An optical mode transformer comprising:

a substrate having a substrate surface;

a lower waveguide cladding disposed on the substrate surface, the lower waveguide cladding having a vertical refractive index distribution that varies according to first substantially stepwise function of a y-coordinate, the y-coordinate representing a distance from the substrate surface, the first function having a maximum value and a minimum value, and the lower waveguide cladding having a horizontal refractive index distribution that varies according to first substantially stepwise function of an x-coordinate, the x-coordinate representing a position in a dimension parallel to the substrate surface and transverse to the long axis, the first function having a maximum value and a minimum value, the lower waveguide cladding further having an upper surface;

a waveguide core disposed on the upper surface of the lower waveguide cladding, the waveguide core having a core refractive index, the ratio of the core refractive index to the maximum value of the first function being at least about 1.3, the waveguide core further having a first end located substantially at a small beam port, a second end defining an intermediate beam port, and an upper surface; and

an upper waveguide cladding disposed on the upper surface of the waveguide core and on the upper surface of the lower waveguide cladding, the upper waveguide cladding having a refractive index distribution that varies as a second function of the y-coordinate and of the x-coordinate, the second function having a maximum value and a minimum value, the ratio of the core refractive index to the maximum value of the second function being at least about 1.3;

the optical mode transformer being configured such that:

in a first region along the long axis between the small beam port and a transition point, the waveguide core cross section has a thickness in a dimension normal to the substrate surface that is substantially constant and equal to a first thickness value;

in a second region along the long axis between the transition point and the intermediate beam port, the waveguide core cross section has a thickness that changes along the long axis from the first thickness value to a second thickness value smaller than the first thickness value, the second thickness being small enough to cause a small mode size of a small light beam received at the small beam port to propagate into at least one of the upper waveguide cladding layer and the lower waveguide cladding layer, thereby enlarging the small mode size; and

in a third region along the long axis between the intermediate beam port and a large beam port, the waveguide core cross section has a thickness that is approximately constant and equal to the second thickness value.

72. A method of fabricating an optical waveguide having a tapered waveguide core using a silicon-on-insulator wafer having a silicon substrate layer, an insulator layer, and a silicon upper layer, the method comprising:

depositing a photoresist layer on the silicon upper layer of the silicon-on-insulator wafer;

applying a mask to the photoresist, the mask having a gray-scale mask pattern that provides an exposure level that varies with position along a length of the mask;

exposing the photoresist and mask to radiation from a radiation source;

performing a selective etching procedure that etches the photoresist and the silicon upper layer and does not substantially etch the insulator, the presence of the photoresist during the selective etching procedure causing a vertically tapered shape to be formed in the silicon upper layer; and

depositing an upper cladding layer over the top and sides of the vertically tapered shape.

73. The method of claim 72, wherein the radiation source comprises an ultraviolet radiation source.

74. The method of claim 72, wherein the radiation source comprises an e-beam source.

75. The method of claim 72, wherein the gray-scale mask pattern has a tapered shape, the gray-scale mask pattern being wide at an end at which the gray scale is darkest and narrow at an opposite end.

76. The method of claim 72, wherein the gray-scale mask pattern has a tapered shape, the gray-scale mask pattern being narrow at an end at which the gray scale is darkest and wide at an opposite end.

77. A method of fabricating an optical waveguide using a silica-on-silicon wafer having a silicon substrate layer and a silica layer, the optical waveguide having a step refractive index distribution in both a vertical and a lateral dimension, the method comprising:

depositing a dielectric waveguiding film on the silica layer;

depositing a photoresist layer of said dielectric waveguiding film;

applying a photomask to the dielectric waveguiding film, the photomask having a stripe defined therein;

exposing the photomask to ultraviolet radiation; and

dry-etching a stripe in the dielectric waveguiding film using a photolithographic process.

78. A method of fabricating an optical waveguide on a silicon substrate, the optical waveguide having a step refractive index distribution in both a vertical and a lateral dimension, the method comprising the steps of:

providing a silica-on-silicon wafer having a silicon substrate layer and a silica layer;

depositing a photosensitive dielectric waveguiding film on the silica layer;

applying a photomask to the photosensitive dielectric waveguiding film, said photomask having a stripe defined therein; and

exposing the photosensitive dielectric waveguiding film to ultraviolet radiation, thereby causing an index of refraction of the waveguiding film to be selectively increased in an area corresponding to the stripe defined in the photomask.

79. The method of claim 78, wherein the photosensitive dielectric waveguiding film comprises a silica-based glass film with germanium or lead incorporated therein.

80. The method of claim 78, further comprising depositing a cladding material over the dielectric waveguiding film.

81. The method of claim 78, further comprising depositing a cladding material over the photosensitive dielectric waveguiding film.

82. The method of claim 81, wherein exposing the photosensitive dielectric waveguiding film to ultraviolet radiation is performed after depositing a cladding material over the photosensitive dielectric waveguiding film, and wherein the cladding material comprises a material that does not substantially absorb ultraviolet radiation.

83. A method of fabricating an optical waveguide on a silicon substrate, the optical waveguide having a graded refractive index distribution in a vertical dimension and a step refractive index distribution in a lateral dimension, the method comprising:

providing a silica-on-silicon wafer having a silicon substrate layer and a silica layer;

successively depositing a first plurality of thin layers of dielectric material on the silica layer, wherein each of the first plurality of thin layers of dielectric material has an effective refractive index larger than a refractive index of the preceding layer;

successively depositing a second plurality of thin layers of dielectric material, wherein each of the second plurality of thin layers of dielectric material has an effective refractive index smaller than a refractive index of the preceding layer;

depositing a photoresist layer on said second plurality of thin layers of dielectric material;

applying a photomask to the uppermost layer of dielectric material, the photomask having a stripe defined therein;

exposing the photomask to ultraviolet radiation; and

dry-etching a stripe in the dielectric material using a photolithographic process, thereby forming a waveguide channel.

84. A method of fabricating an optical waveguide on a silicon substrate, the optical waveguide having a graded refractive index distribution in a vertical dimension and a step refractive index distribution in a lateral dimension, the method comprising:

providing a silica-on-silicon wafer having a silicon substrate layer and a silica layer;

successively depositing a first plurality of thin layers of photosensitive dielectric material on the silica layer, wherein each of the first plurality of thin layers of photosensitive dielectric material has an effective refractive index larger than a refractive index of the preceding layer;

successively depositing a second plurality of thin layers of dielectric material, wherein each of the second plurality of thin layers of dielectric material has an effective refractive index smaller than a refractive index of the preceding layer;

applying a photomask to the uppermost layer of photosensitive dielectric waveguiding film, said photomask having a stripe defined therein; and

exposing the layers of photosensitive dielectric waveguiding film to ultraviolet radiation, thereby causing the index of refraction of each of the layers of photosensitive dielectric waveguiding film to be selectively increased in an area corresponding to the stripe defined in the photomask.

85. The method of claim 83, further comprising depositing a cladding material over the uppermost layer of dielectric waveguiding film.

86. The method of claim 84, further comprising depositing a cladding material over the uppermost layer of photosensitive dielectric waveguiding film.

87. A method of fabricating an optical waveguide on a silicon substrate, the optical waveguide having a graded refractive index distribution in a vertical dimension and a graded refractive index distribution in a lateral dimension, the method comprising :

providing a silica-on-silicon wafer having a silicon substrate layer and a silica layer;

successively depositing a first plurality of thin layers of photosensitive dielectric material on the silica layer, wherein each of the first plurality of thin layers of photosensitive dielectric material has an effective refractive index larger than a refractive index of the preceding layer;

successively depositing a second plurality of thin layers of dielectric material, wherein each of the second plurality of thin layers of dielectric material has an effective refractive index smaller than a refractive index of the preceding layer;

applying a photomask to the uppermost layer of photosensitive dielectric waveguiding film, said photomask having a grayscale pattern defined therein; and

exposing the layers of photosensitive dielectric waveguiding film to ultraviolet radiation, thereby causing the index of refraction of each of the layers of photosensitive dielectric waveguiding film to be selectively increased in proportion to the grayscale pattern defined in the photomask and producing a graded index of refraction along the lateral dimension of each of the layers of photosensitive dielectric waveguiding film.

88. A method of fabricating an optical waveguide on a silicon substrate, the optical waveguide having a tapered high-refractive-index waveguide core and a cladding having a graded refractive index distribution in a vertical dimension and a step refractive index distribution in a lateral dimension, the method comprising:

providing a silica-on-silicon wafer having a silicon substrate layer and a silica layer;

successively depositing a first plurality of thin layers of photosensitive dielectric material on the silica layer, wherein each of the first plurality of thin layers of

photosensitive dielectric material has an effective refractive index larger than a refractive index of the preceding layer;

bonding a silicon layer on the uppermost layer of the first plurality of thin layers of photosensitive dielectric material;

depositing a photoresist layer on the silicon upper layer;

applying a first photomask to the photoresist, the first photomask having a gray-scale mask pattern that provides an exposure level that varies with position along a length of the first photomask;

exposing the photoresist and photomask to radiation from a radiation source;

performing a selective etching procedure that etches the photoresist and the silicon upper layer and does not substantially etch the insulator, the selective etching procedure causing a vertically tapered shape to be formed in the silicon upper layer;

successively depositing a second plurality of thin layers of dielectric material, wherein each of the second plurality of thin layers of dielectric material has an effective refractive index smaller than a refractive index of the preceding layer;

applying a second photomask to the uppermost layer of photosensitive dielectric waveguiding film, said second photomask having a stripe defined therein; and

exposing the layers of photosensitive dielectric waveguiding film to ultraviolet radiation, thereby causing the index of refraction of each of the layers of photosensitive dielectric waveguiding film to be selectively increased in an area corresponding to the stripe defined in the second photomask.

89. The optical mode transformer of claim 1, wherein the second end is optically coupled to a large beam port, and wherein a light beam having an initial mode size enters the waveguide core from the small beam port and exits at the large beam port having a final mode size larger in a dimension normal to the substrate surface than the initial mode size.

90. The optical mode transformer of claim 1, wherein the second end is optically coupled to a large beam port, and wherein a light beam having an initial mode size enters at the large beam port and exits the waveguide core at the small beam port having a final mode size smaller in a dimension normal to the substrate surface than the initial mode size.

91. The optical mode transformer of claim 13, wherein the second end is optically coupled to a large beam port, and wherein a light beam having an initial mode size enters the waveguide core form the small beam port and exits at the large beam port, having a final mode size larger in a dimension parallel to the substrate surface and transverse to the direction of light propagation than the initial mode size.

92. The optical mode transformer of claim 13, wherein the second end is optically coupled to a large beam port, and wherein a light beam having an initial mode size enters the waveguide core from the large beam port and exits at the small beam port having a final mode size larger in a dimension parallel to the substrate surface and transverse to the direction of light propagation than the initial mode input beam.

93. The optical mode transformer of claim 25, wherein the second end is optically coupled to a large beam port, and wherein a light beam having an initial mode size enters the waveguide core from the small beam port and exits at the large beam port having a final mode size larger in a dimension parallel to the substrate surface and transverse to the direction of light propagation than the initial mode size.

94. The optical mode transformer of claim 25, wherein the second end is optically coupled to a large beam port, and wherein a light beam having an initial mode size enters the waveguide core at the large beam port and exits t at the small beam port having a final mode size smaller in a dimension parallel to the substrate surface and transverse to the direction of light propagation than initial mode size.

95. The optical mode transformer of claims 1, 2, 13, 14, 36, 47 or 70, wherein the critical thickness value is defined as approximately $\lambda_0 / \left(4\sqrt{n_c^2 - n_{cl}^2}\right)$, where λ_0 is the wavelength of the light beam in a vacuum, where n_c is the refractive index of the waveguide core, and wherein n_{cl} is the index of refraction of the waveguide cladding.